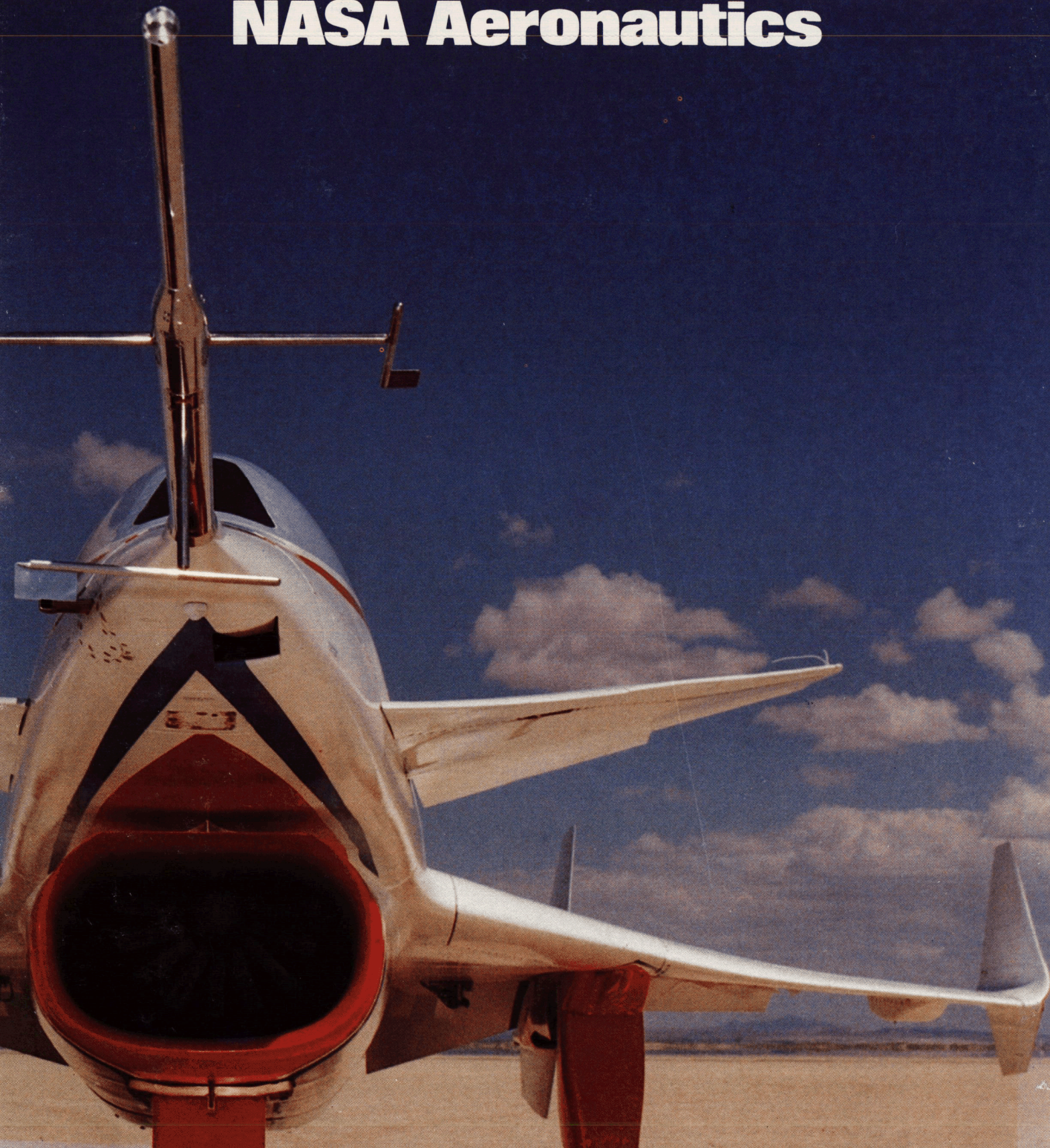
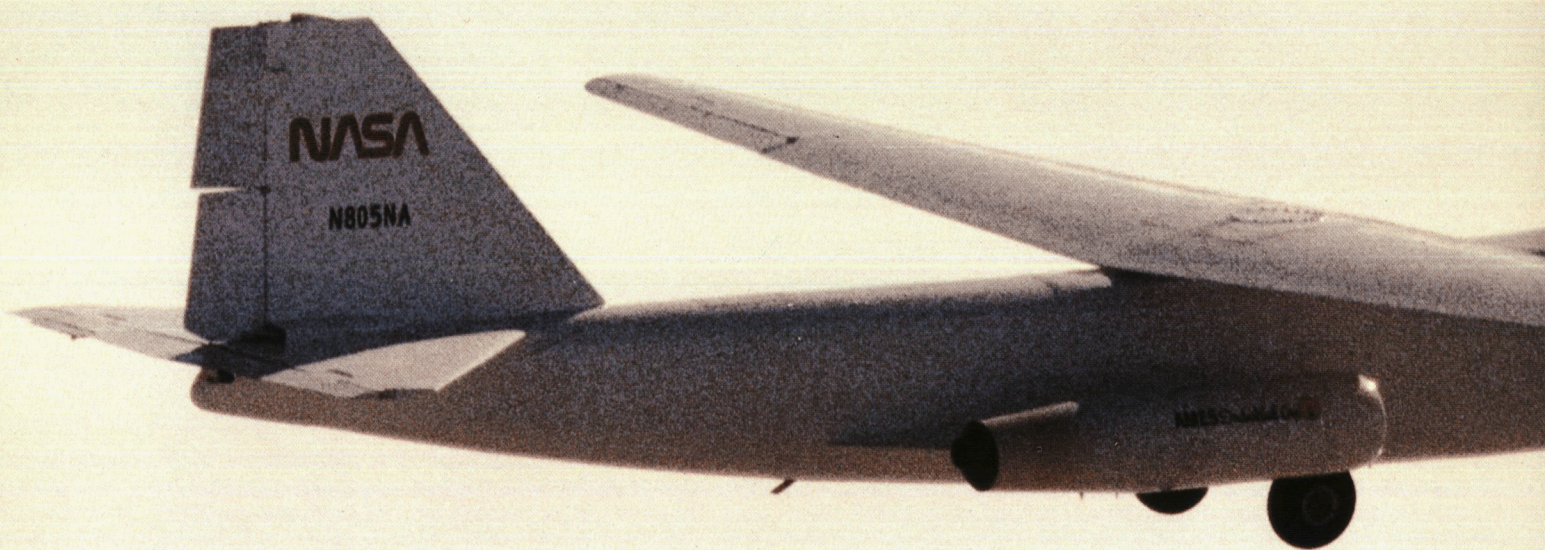


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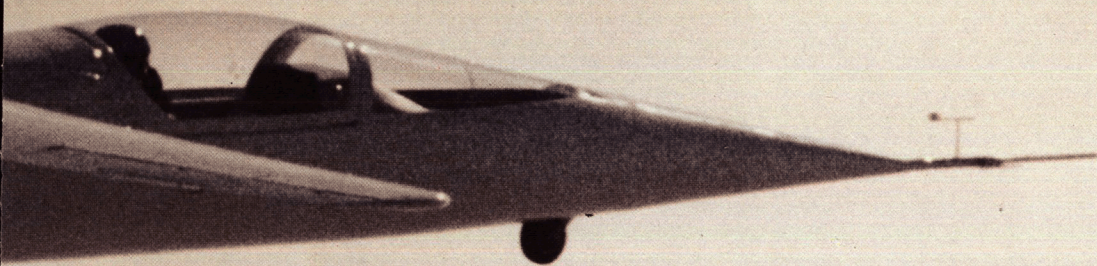


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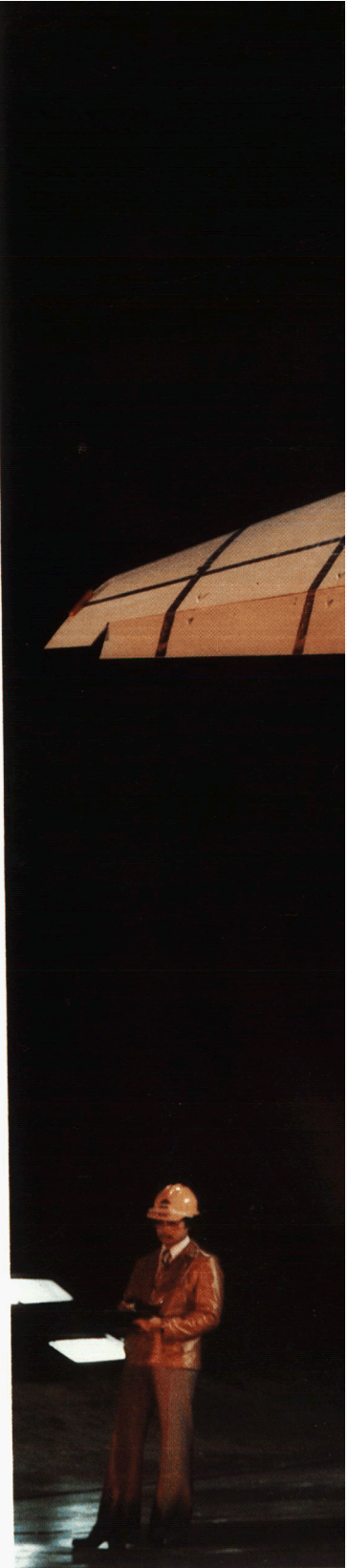


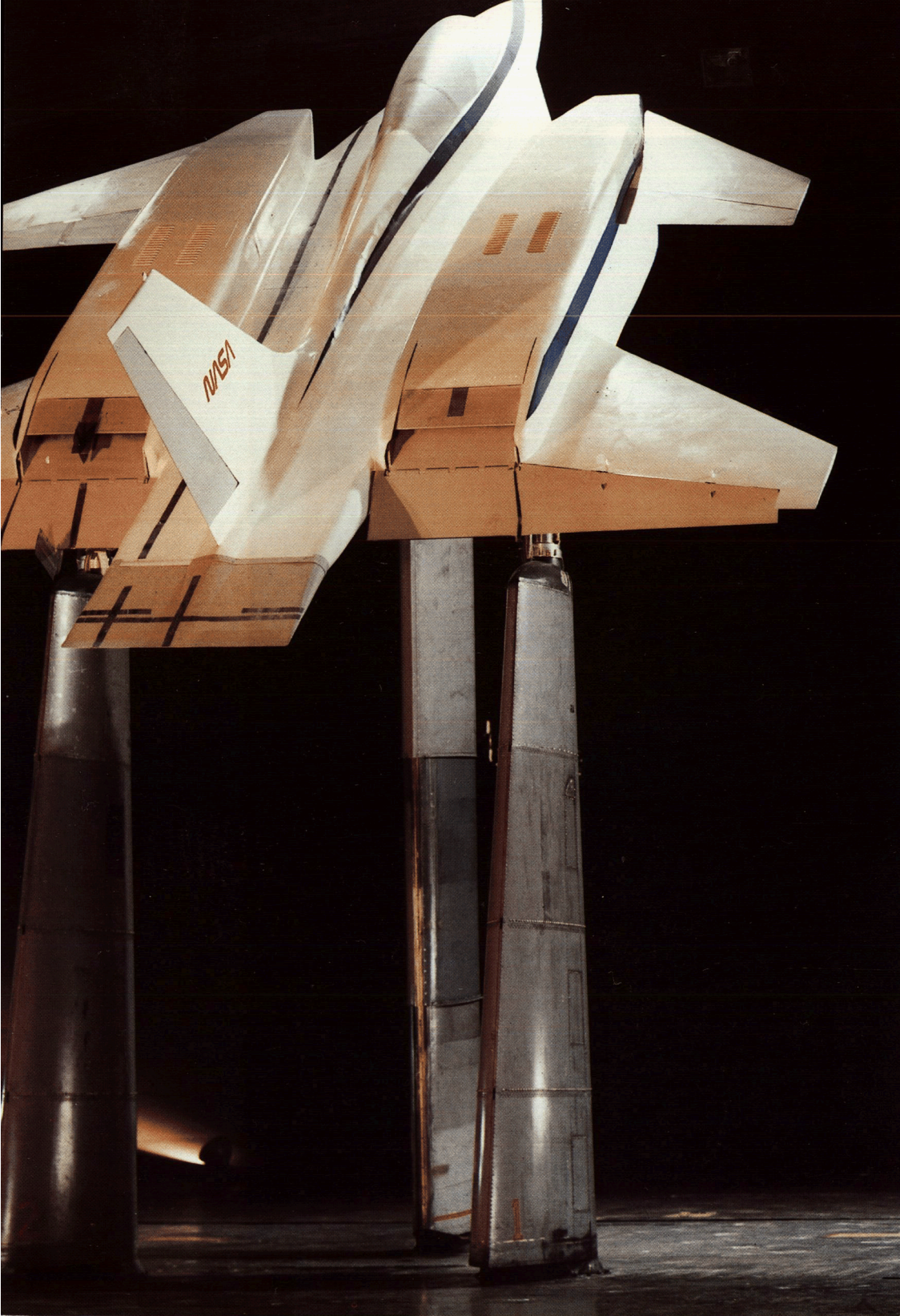
David A. Anderton

Public Affairs Division
NASA Headquarters
Washington, DC 20546

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Introduction to a Mystery

There is a grand mystery to flight, a mystery that still defies analysis and complete understanding.

The erratic flapping of a butterfly, the swift swoop of a falcon, the soaring silence of a sailplane share that mystery and partially reveal only three of its many faces.

Now, we are almost two centuries into the experiences of flight, almost 200 years from the time the Montgolfier brothers first harnessed hot air to hoist their demonstration balloons into the skies of France. The years between then and now have added immeasurably to our store of aeronautical knowledge. The refinements of theory and the gathering of practical data by engineers and scientists have increased our understanding of why flight is possible. But, as late as these latter decades of the Twentieth Century, much still remains hidden from our view.

Realize, for example, that there is still no way to predict accurately the amount of turbulence in airflow, and its ef-

Concept for an advanced supersonic fighter is shown before testing in the Ames Research Center 40- by 80-foot wind tunnel. The fighter model is intended to have vertical or short takeoff and landing capability,

and uses thrust vectoring to achieve that goal. The exhaust from twin General Electric J-79 turbojets is directed over the wing flaps to increase their lift increment for short-field performance. Later, a thrust aug-

mentation system will be added to increase the available thrust and achieve vertical takeoff. This particular model is three-quarters full-scale, and was mounted for low-speed tests in the Ames tunnel facility.

NASA: What and How



Conceptual design studies are a major portion of the workload in NASA test facilities. Here, a lift-fan powered aircraft, intended for vertical takeoff, is being inspected before being

tested in the Ames Research Center's 40- by 80-foot wind tunnel. This huge facility is capable of handling many full-scale aircraft, or models approaching the size of full-scale

versions. Note the lifting fan near the nose of this aircraft, and the two vertical jet exhausts, one from each nacelle, aft of the model suspension system.

fect on flight. In the controlled environment of today's wind tunnels, turbulence affects test results to a degree still to be exactly determined. Turbulence is an important component of flight mechanics, and a very complex one. It is so complex, in fact, that it cannot even be analyzed totally by the fastest and most capable contemporary computers.

But it can be approximated, and quite closely, in some cases. So can some of the lesser mysteries of flight: Those that cause an airplane to turn and climb and dive; those that make it possible to build a light and simple structure that can withstand the winds of super-hurricane force hurtling across a wing; those that extend the range of an airplane so that it can cross oceans.

Aeronautical research, then, is often a science of approximations. It attempts to understand the "why," not just the "how" of flight. It does this, because understanding how a thing works is the main path toward making it work better. So aeronautical research also becomes the science of the approximations of improvement.

The National Aeronautics and Space Administration was chartered officially to conduct aeronautical research, among its other defined tasks. That was the only task for NASA's predecessor, the National Advisory Committee for Aeronautics, founded in 1915. The National Aeronautics and Space Act of 1958, the legislation that established NASA, states that the general welfare and security of the United States require adequate provision to be made for aeronautical activities, and that these activities should be so conducted as to contribute materially to one or more of these objectives:

- The expansion of knowledge of phenomena in the atmosphere.
- The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical vehicles.
- The preservation of the role of the United States as a leader in aeronautical science and technology.



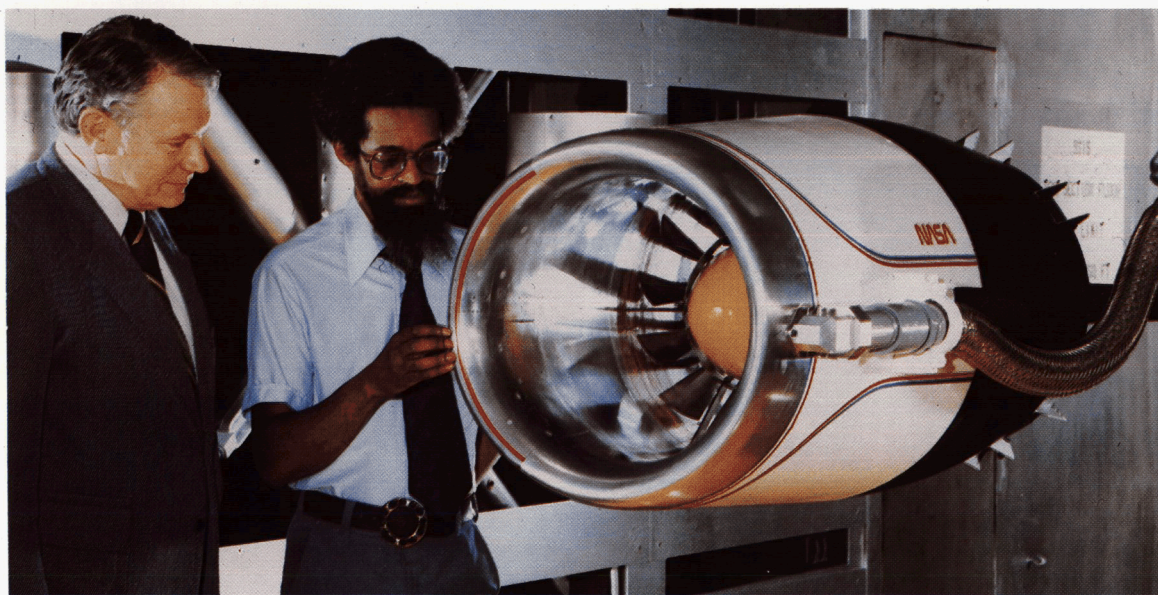
A joint NASA-Navy program uses this Grumman F-14A fighter as a flight research vehicle to investigate a new control system concept originating at the Langley Research Center. The new system features an aileron-rudder interconnect (ARI) for improved handling qualities at high angles of attack. This F-14A has been modified to include a spin-recovery parachute and two-position deployable canard surfaces. The canards, shown extended from the fuselage sides just forward of the pilot's position, are part of the spin-recovery system on this research aircraft.

● The most effective utilization of the scientific and engineering resources of the United States in order to avoid unnecessary duplication of effort, facilities and equipment.

NASA research scientists, part of a team that includes industry, universities, other government organizations, and laboratories, both private and government, work toward those broad objectives.

Specifically, NASA aims its research toward the advancement of both civil and military aeronautics, pointing toward new concepts of flight, seeking new approaches to solve the ever-changing, ever-complex problems of transportation, and evolving new ideas to stimulate the designers of tomorrow's aircraft and aeronautical vehicles.

NASA's broad field of aeronautical research has as its primary subjects the vehicles and powerplants that use the Earth's atmosphere for flight. It also is concerned with the aeronautical aspects



of space vehicles that depart from, or land on, the Earth.

The major share of this work is done at four NASA centers: Langley Research Center, Hampton, Virginia; Ames Research Center, Moffett Field, California; Dryden Flight Research Center, Edwards, California; and the Lewis Research Center, Cleveland, Ohio.

Additional studies are done at other NASA labs, or at the laboratories and facilities of other government agencies. Private industry makes major contributions, from self-supported research and development programs, and

from NASA-funded programs. Universities have a unique contribution to make that reflects their long tradition of academically oriented research studies. The military services become partners with NASA on specific programs or projects, or long-term participants in one or more fields of investigation.

NASA research is planned to support the needs of operating agencies, such as the Department of Defense and the Department of Transportation, and of the aerospace industry, with its myriad of ideas for future designs and development.

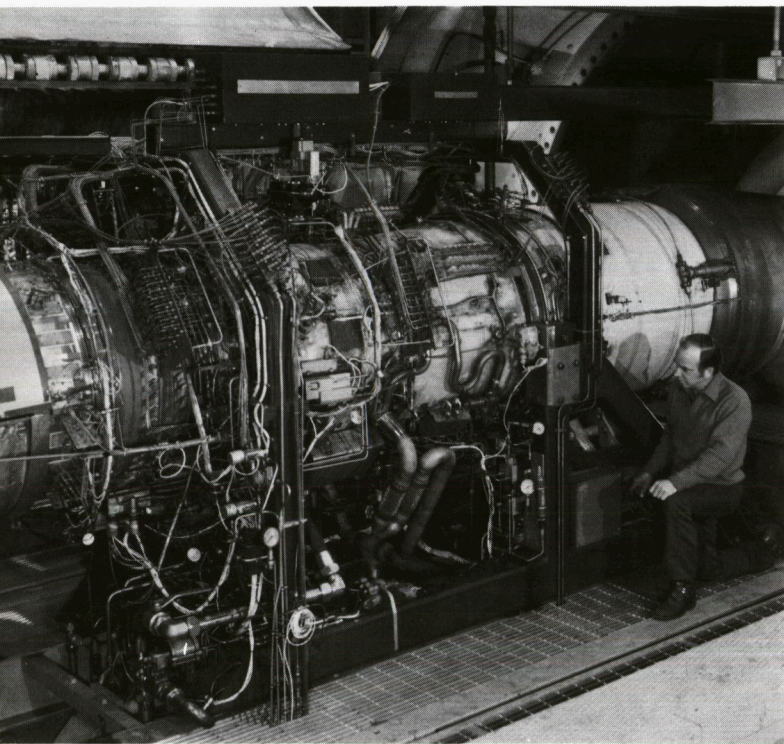
To solve the problem of engine inlet air flow separation, Lewis Research Center and Grumman Aircraft Corporation conducted a joint test project using this typical nacelle installation which houses the engine of a VISTOL powerplant. An annular jet of air was blown over the internal surface of the engine inlet to delay the separation of air flow from that region. The useful nacelle angle-of-attack range was essentially doubled by using the blown jet. This first successful demonstration of the principle could lead to substantially lighter and more compact inlet designs for VISTOL aircraft.

Driven by Air Movements

An advanced turbofan engine that powers U.S. Air Force and Navy supersonic fighters is shown in the test section of a high-altitude facility at NASA's Lewis Research Center. The test section door has been

swung up and open for access to the engine. Almost all of the external visible mass of piping and cabling is test instrumentation, installed only for the research program in the Lewis facility. For a typical test program, both

the engine and the altitude inside the test chamber are controlled to verify engine performance over a wide range of ambient conditions of speed and altitude.



The driving force behind NASA research is the simple fact of the overwhelming importance of air transportation, whether it be the movements of people, freight, or weapons. In a dynamic world that is becoming more international by the day, and where developing countries are spawning major industrial complexes that generate passenger and freight traffic, air transportation is probably the single

most important supporting service.

Today, tourists and business travelers are flying across seas and continents for vacations or commerce. Expanding industries reach out to new sources of raw materials or labor, generating a new traffic pattern for the flow of goods. Oil, the common denominator of movement, has alone remodeled the air travel patterns of the globe.

Projections for the future

of air transportation almost stagger the imagination. A major problem is how to handle the demands for growth, particularly in a world of apparently decreasing oil supplies and escalating prices. More efficient aircraft designs are needed, and that requirement demands new kinds of powerplants, new approaches to lightweight and efficient structures, and new ways to increase range by decreasing drag. More aircraft movements carry the potential for increased neighborhood near major airports around the world, and already have crowded the traffic lanes of the air to the point of near-saturation.

NASA looks ahead, working on problems that will obviously require solutions before the next ten years have passed. But a large portion of NASA work also is directed to the immediate problems of today, whether they be some aerodynamic quirks of a fighter just entering operation, or the strains on a production engine being boosted to new limits of performance.

Four Ways to Research

NASA aeronautical research is categorized in a quartet of headings: *Proof of concept, extension of the art, future needs, and problem solving.*

Proof of concept is an approach that often, but not always, requires the building and testing of a special aeronautical vehicle. The best-known examples are the famed X-series of research aircraft developed by NACA and industry in the late 1940s and subsequently. A more recent example is the joint Navy-Army-NASA-Bell XV-15, a unique rotorcraft with a potential for both military and civil use. Technology is available for proof of concept, but needs to be transformed into a tangible flying machine for the ultimate test.

Extension of the art takes as a basis the contemporary state of that art, and builds on that foundation. Today's subsonic transport aircraft are, for example, well understood. But continuing research in aerodynamics, propulsion, structures, materials and avionics indicates that tomorrow's



Hovering in company tests before delivery to NASA, the first of two Bell Tilt-Rotor Research Aircraft (TRRA) displays its characteristic lifting and thrusting rotor system in the vertical-flight mode. The large rotors serve as lifting devices, when they are operating in the horizontal plane as shown here. The XV-15 (its military designation) can lift off vertically and then, by a progressive forward tilting of the rotor assemblies, can translate the vertical lifting force into forward thrust. This project is a joint program shared by the Army and NASA. The basic purpose is to conduct a thorough investigation and evaluation of the tilt-rotor system for advanced vertical and short takeoff and landing aircraft.

row's transports could be improved by the incorporation of new ideas. The art has been extended, and that body of knowledge is available to industry as foundation stones for the next-built generation of aircraft.

Future needs call for the broadest research goals, sometimes the end point of work that would seem to have little practical current application. An example: The investigation of highly specialized and very expensive materials for use in some future powerplant. At today's prices, the cost of using the materials would be prohibitive; but historically, the costs of new materials decrease as the number of applications increases. And there never will be any future applications unless research is done now to lead toward them.

Problem solving is obvious research. The best of designs, after painstaking analysis, extensive wind-tunnel testing and exploration of the flight envelope—perhaps even after certification and operation



for some years, in the case of civil aircraft—may develop a problem that could not have been predicted earlier, a problem related perhaps to long-time exposure to some external force. That kind of problem-solving is typical of the work that NASA has done.

These four categories further subdivide themselves into two broad areas. The first is disciplinary research, dealing with a branch of the aeronautical art.

Aerodynamics, propulsion, structures and materials are typical areas where disciplinary research is conducted.

The second is research applied to specific classes of aircraft, for example, subsonic transports or fighters. In either of these classes of research, flight vehicles may be used to prove a concept, test a refinement, or to carry some particular research experiment into an environment not so efficiently reached on the ground.

The second of the two Tilt-Rotor Research Aircraft (TRRA), built by Bell Helicopter for a joint NASA-Army program, is shown in horizontal flight. Fixed wing surfaces carry the rotor assemblies and powerplant nacelles, and generate lift for horizontal flight.

The Tools of Research

The general popular impression of NASA's aeronautical research visualizes a huge wind-tunnel section containing a full-sized airplane mounted on struts, dwarfing the researcher standing near to give scale. Wind tunnels were, and are, a most important component of NASA facilities, and a very long-standing method of conducting research experiments.

They provide a means to test accurate scale models, or even full-size actual aircraft, over some of the normal speed range encountered in flight. These are carefully controlled tests, with a calibrated airstream rushing past the mounted model. Accurate balances measure the forces, and computers translate those measurements of pounds of tension and compression into coefficients of lift, drag and pitching moments.

But before wind-tunnel testing occurs, analytical methods traditionally are used to predict the behavior of an aircraft in flight. Once laboriously done with pencil,

slide rule and perhaps a desk calculator, such analyses now are the special provinces of high-speed computers. They process codes fashioned to forecast flow patterns and forces around a fuselage or wing, or their juncture.

The simulator offers a third approach to research. Driven by many computational circuits that calculate the behavior of an aircraft and present it in a display, the simulator offers a way of "flying" an aircraft before it is built. The characteristics of the vehicle, determined from drawings, analysis and model tests, are programmed into the computer. Played back to

A dynamically similar scaled model of the Grumman F-14A fighter aircraft is shown during a test program in the Langley Research Center full-scale tun-

engineers or pilots "flying" the new design, they reveal the good and bad qualities.

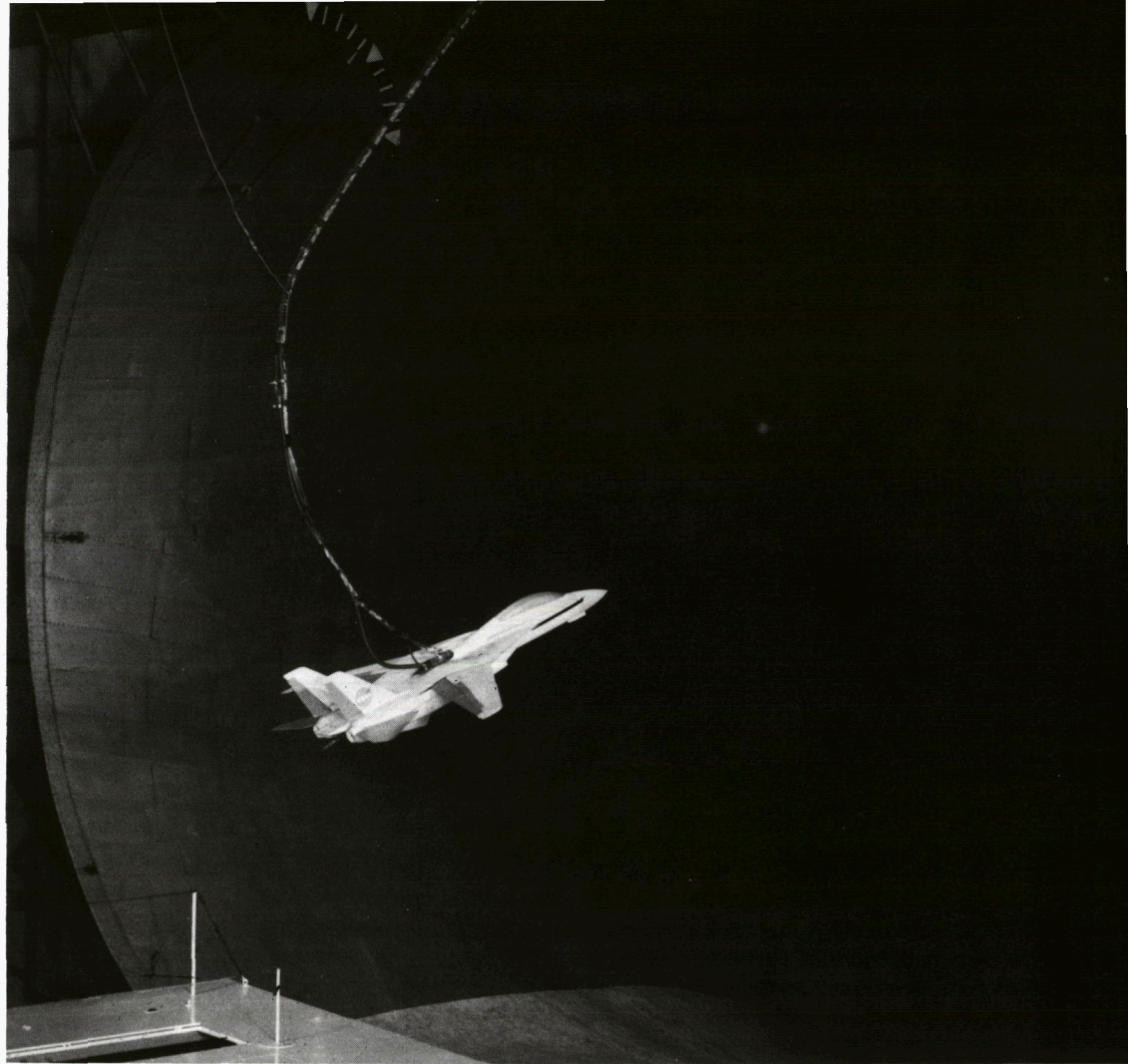
A simulator can be used to duplicate an existing aircraft's flying qualities, and to present them in a realm that might endanger a crew on a real flight. It can refine an airplane design before final production drawings are released to the shops. It can study the effects of minor or major changes in the aircraft's components, powerplants, or other systems.

Analysis, model testing and simulation all contribute to the understanding of the performance of a flight vehicle. One step remains: Flight

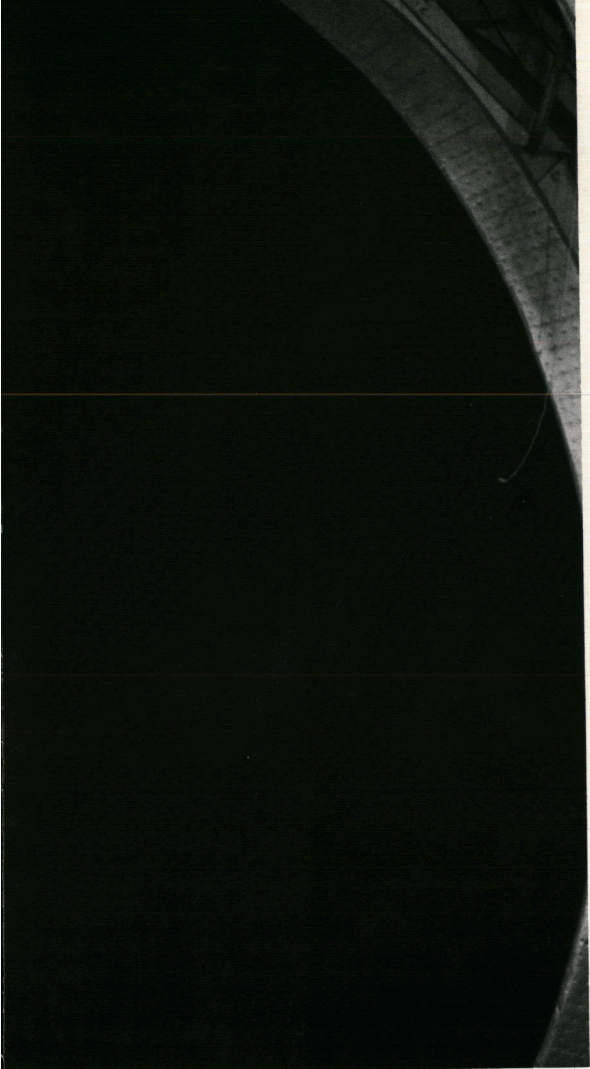
nel. The tethered model can be flown from pilot stations in the tunnel to simulate behavior at the low-speed end of the F-14A's flight envelope. Studies of the

of the vehicle itself. NASA research pilots, who also are engineers, conduct a meticulous program that gradually probes the flight envelope, edging toward the speed, altitude and load limit that will define the final performance of the aircraft itself. This full-scale research furnishes answers that will corroborate, extend and perhaps correct the inputs from analysis, wind-tunnel tests, and simulation.

These are the four major tools of NASA researchers. They have been used singly, or in concert, to explore problem areas in the safety, efficiency, or comfort of aircraft.



Energy-Efficient Aircraft




airplane's stability and control at high angles of attack, such as demonstrated here, may lead to suggestions for improvements in performance, or handling, or both.

Commercial transports burn about ten billion gallons of aviation fuel each year. A five percent improvement in their overall efficiency would save the United States 500 million gallons of fuel annually. And five percent is well within the potential for improvements in aerodynamics, propulsion, and other active systems of commercial transports.

NASA's Aircraft Energy

Efficiency (ACEE) program is a ten-year planned effort that looks simultaneously at near-term and far-term problems. It attempts to develop solutions that can be applied to existing transports, to their derivatives expected within a few years, and to new classes of aircraft designed specifically to be fuel-efficient.

The broad goal of the ACEE program is the de-



The exceptional aerodynamic cleanliness of this prototype general aviation aircraft resulted in outstanding high-speed performance, achieved apparently by attaining a high degree of natural laminar flow. NASA evaluated the aircraft in a flight-test program at Langley, to determine its drag characteristics and to ascertain the extent of the laminar flow characteristics. Results are applicable not only to the design of future light, general-aviation aircraft, but also to the long-term study of laminar flow control underway at NASA.

Spinning characteristics of a typical light single-engined aircraft were studied in a progressive program at the Langley Research Center. The test series began by observing the behavior of small dynamically similar models in the Langley spin tunnel. Later, radio-controlled models were flown in small-scale, free-flight tests for comparison with spin-tunnel results. Then the full-scale aircraft began its flight research program to investigate the basic

qualities and quantities of the spin, and to relate them to the results obtained from model tests. As part of the aircraft research program, a number of different vertical and horizontal tail configurations were evaluated for their effect on aircraft spin characteristics. Modifications to the standard airplane also included wingtip booms for instrumentation and a spin-recovery chute mounted on an external bracket below and behind the base of the rudder.



development of an inventory of technology, available to the manufacturers of transports and powerplants in the United States. Most of the research and technology projects grouped under this program are being done by industry, the constructors of airframes and engines. Their existing facilities and test aircraft can do the work efficiently. Additional efforts are being made by the commercial airlines, who furnish their special inputs to the seekers of operational solutions.

ACEE is a continuation of an earlier program that NASA had instituted before there was a fuel crisis. During the early 1970s, the agency began studies of Advanced Transport Technology (ATT), with the goal of examining new concepts and their effect on productivity. Many of the ideas that originated then—supercritical aerodynamics, composite structural materials, and active control systems—became foundation stones for current ACEE work, because they also reduce fuel consumption.

The Energy-Efficient Transport (EET) studies, one of six technology programs that comprise the overall ACEE work, serve to illustrate the interdisciplinary approach to new solutions. Commercial airlines are concerned with three operational factors: The direct operating cost (DOC), the range, and the weight of the aircraft. More than half of the current DOC is charged to fuel; obviously, any reduction in fuel consumption would mean a major improvement in DOC. Reductions in drag, and other attainable improvements in the ratio of lift to drag, will improve the range capabilities. New materials and structural concepts, combined with the use of active controls, can produce lighter and smaller airframes.

The NASA supercritical wing design and its subsequent development is one method for improving the lift-drag ratio. This unusual airfoil section controls the flow over the wing; it avoids the sudden increase in drag that would occur with con-

Four of the empennage geometries evaluated on NASA 501, the spin-research aircraft typical of light single-engined planes, demonstrate different



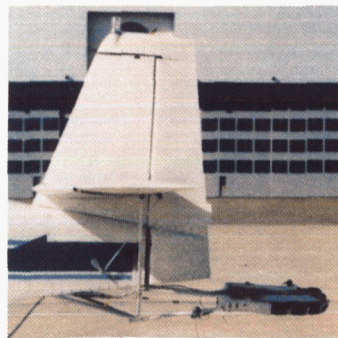
Tail 2



Tail 3



Tail 4



Tail 6

ventional airfoils operating in high-speed airflow. Further, it shows this lower drag feature in spite of an increased

aerodynamic approaches to the problem of spin recovery. Tail 3 features a small end plate on top of the rudder. Tail 4 has a low-set horizontal surface, but Tail 6 has the horizontal tail set higher, on the lower portion of the vertical fin.

NASA 501, the spin research aircraft typical of light single-engined designs, is shown in flight above the test area adjacent to the Wallops Flight Center, Wallops Island, Virginia. Number 2 on vertical tail indicates that the plane is flying with the second of several empennage configurations developed for improved spin recovery. Note the instrumentation booms extending forward from each wingtip, and the spin-recovery parachute mounted on the aft fuselage behind and below the horizontal tail.

thickness of the wing section. Consequently, a properly designed supercritical wing has three direct benefits that improve aircraft efficiency: First, it reduces wing drag; second, it increases internal volume for fuel storage; third, it increases the structural efficiency of the wing and leads to lower weight.

The total benefit of a well-designed supercritical wing could be a reduction of 10 to 15 percent in the amount of fuel burned for a specified trip.

Other aerodynamic improvements with fuel-saving potential include winglets, small surfaces mounted at and above the wingtips; high-lift devices used during climb and descent; active controls, to reduce the size—and therefore the drag and weight—of horizontal and vertical tail surfaces; and careful integration of the propulsion system into the aerodynamic flow contours of the aircraft.

One method with great potential for drag reduction is laminar flow control (LFC),

Shorter Takeoffs, Lower Noise



using suction through multiple slots in the wing surface to maintain smooth, low-drag airflow over the wing. NASA's interdisciplinary approach focuses on a lightweight, strong and rigid structure combined with a suction system that could make practical LFC systems a reality.

Improvements in propulsion include the development of engine components—compressors, combustors, turbines—that have higher individual efficiencies. Beyond that work, there is potential for development of a basically new powerplant around the older concept of a turboprop. That type of engine was once a way station on the journey from piston engines driving propellers to jet engines. But now, the fuel efficiency of such an engine, coupled with developments in propeller technology, have spurred a new look at this old idea.

The big difference is in the appearance of the propeller. Instead of the three or four blades commonly seen on

propellers used with piston engines, the new propeller has multiple blades, curved and shaped for maximum efficiency at high rotational speeds. These scimitar shapes have been tested in wind tunnels and will evolve through small-scale models to a full-size development, if the preliminary studies point in that direction.

The example of the ACEE program shows how NASA functions. It involves a team effort by government agency and industry. It crosses the boundaries of aeronautical disciplinary areas, and integrates them into a planned and phased program. It uses the four basic classes of research tools available to NASA: *Computers*, that analyze flow, performance and design characteristics; *wind tunnels*, that test scale models of components, or of complete aircraft; *simulators*, that verify the effects of small changes in existing airplanes; and *flight vehicles*, such as the drones that will carry the examples of advanced wing designs into the air.

The broad aims of the ACEE program apply best to long-range transports that carry a hundred or more passengers across continents and oceans. In such long-distance, high-capacity flights, increased aircraft efficiency really pays in terms of fuel saved. Fuel costs, once a relatively small part of the direct operating costs of an airline, have become instead a major portion of those charges. That fact is true equally for the smaller third-level air carriers as well as for the major trunk and international airlines.

As fuel availability and cost change the pattern of air travel, and as the shorter route segments once flown by the major carriers are taken over by the smaller ones, new demands may arise for categories of aircraft not yet developed. In some cases, the requirements of an air carrier's route structure may best be served by the introduction of a large-capacity short takeoff and landing (STOL) airplane.

The technology of STOL has long been a subject of

great interest at NASA centers. Tied closely to it has been the investigation of noise, because one use of STOL and vertical takeoff and landing (VTOL) aircraft is planned around the concept of close-in airports. Such locations demand aircraft with a low noise level. This is not to imply that noise reduction is not necessary at major terminals; it is.

Several factors have altered the noise environment around airports since jets first appeared on the scene in the late 1950s. There has been a tremendous construction boom, and undeveloped land everywhere was used for suburban homes. Much of the undeveloped land around major cities was also around the major airports that served those cities. Consequently, houses were built right up to the borders of the field, in some cases. There was also a rapid expansion of travel, which meant more flights and therefore more airplanes to generate more noise around the airport. Finally, the first-generation turbojet engines

The Quiet Short-haul Research Aircraft (QSRA) is a proof-of-concept vehicle to investigate the technology of a propulsive lift system that uses wing upper-surface blowing. It utilizes a de

Havilland C-8A "Buffalo" light military transport loaned by the Army for the program, and modified by The Boeing Company to incorporate the propulsive lift system in an en-

tirely new wing design. Here the QSRA is being checked out by Boeing company pilots before delivery to NASA's Ames Research Center for the major portion of its research flying.



in the transports gave way to later and more efficient turbofan engines; but these later powerplants had a different noise pattern which changed the perceived sound levels. These factors, although they did not initiate NASA programs in noise research, certainly were additional spurs to accomplishment.

NASA has developed methods for lowering the noise level of large jet transports by an acoustic treatment of the engine nacelles. The "quiet" nacelle found wide acceptance among airline operators. But that was, obviously, an interim solution. The better way was to develop a "quiet" engine, and NASA—in a joint program

with industry—developed such an experimental powerplant that produced a significant reduction in generated noise.

That work also led to another developmental powerplant designated QCSEE, for Quiet, Clean, Short-haul Experimental Engine. It began test runs at the Lewis Research Center in the late 1970s. The goal of the program was to produce a powerplant for a four-engine, 150-passenger STOL transport with a small and relatively low noise footprint. The STOL technology around which the QCSEE was developed utilized the engine exhaust to produce incremental lift. In one case, the

exhaust was blown directly over external flaps to produce the added lift for STOL. In the other, part of the bypass air was ducted to blow over the upper surface of the wing to generate additional lift. Both these types of engines were built and successfully tested.

A parallel step was the development of the QSRA (Quiet Short-haul Research Aircraft), which originated as a proof-of-concept vehicle and a research tool. It was intended to validate the technology of a propulsive lift system that used upper-surface blowing. Additionally, its operations would develop criteria for certification of future transports that used

propulsive lift. The geometry of the QSRA is typical of a short-haul transport, and the low-speed flight regime is the area of particular interest. Noise levels, flying qualities, stability and control, and operational constraints are items on the QSRA test program.

The wing of the QSRA, which incorporates the propulsive lift system, was designed and built by The Boeing Company, and installed as a modification to a de Havilland of Canada C-8A "Buffalo," a U.S. Army light STOL transport. Flight evaluation is being done at the Ames Research Center, designated to lead NASA's VTOL and STOL programs.

Revolutionary Lift

Rotary-wing aircraft are in a class by themselves. Capable of both STOL and VTOL performance, and uniquely able to hover and perform other unusual aerial maneuvers, these aircraft pose problems that have intrigued researchers at NASA and elsewhere for decades. The problems stem from the nature of their lift generation. Their "wings" are rotating blades, whirled at high speeds in a horizontal plane, and adjusted individually by a complex mechanism in order to produce motion about three axes.

Two different flight vehicles are the keystones of NASA's rotary-wing research programs. First of these is the Tilt-Rotor Research Aircraft (TRRA), built by Bell Helicopter Textron under a joint effort that originally was shared by the Ames Research Center and the Army's Air Mobility Research and Development Laboratory. The TRRA, or XV-15 (its military designation), has twin rotors and powerplants mounted at the ends of a high wing. The



The Army/NASA Rotor Systems Research Aircraft (RSRA), developed by Sikorsky Aircraft, is shown in level flight near the Ames Research Center. Two of these unusual craft were built for the joint program, one with

the ability to be flown as a compound helicopter with fixed wings and a forward propulsion system as add-on features. The second, shown here, was designed to fly as a pure helicopter to furnish baseline test data,

and to investigate rotor systems and other helicopter features on its own. One notable identification feature of the RSRA helicopters is the tall vertical T-tail that carries the anti-torque rotor.

One of two Rotor Systems Research Aircraft (RSRA) developed for a joint NASA-Army program by Sikorsky Aircraft, this particular RSRA is shown in its compound helicopter form. The fixed wings carry some of the lift in horizontal flight, and

help to unload the rotor system. A standard Sikorsky S-61 rotor head is used in the design. The turbofan engines mounted on the fuselage flanks are for forward propulsion; the lifting rotor is driven by twin turboshaft engines mounted above the fuse-

lage. A unique crew escape system was developed for this research aircraft, which ejects the three-man crew in split-second sequencing following ejection of the rotor blades.



rotors can be tilted from horizontal, permitting vertical flight, to vertical, permitting horizontal flight.

Two XV-15 aircraft were built. The first, after a few hours of check flights, was mounted in the Ames full-scale tunnel and tested exhaustively. The second, which first flew in the hover mode in early 1979, became the primary flight-research subject. Both aircraft now are being flown in a detailed re-

search program which is continuing.

The second type is the Rotor Systems Research Aircraft (RSRA), built by Sikorsky Aircraft Division of United Technologies Corp. for NASA and the Army. The two aircraft built under the program use Sikorsky S-61 helicopter rotor heads as the basic lifting system, but are designed to be able to test a wide variety of rotor systems. The RSRA can be flown as a

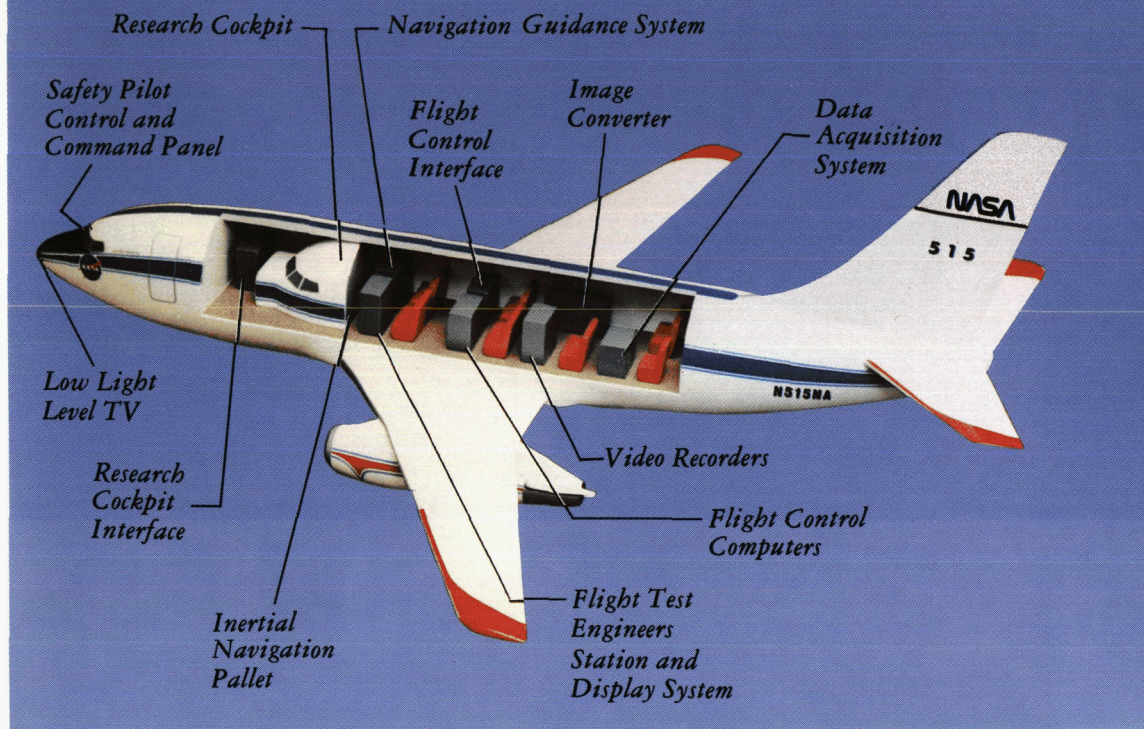
conventional helicopter, or as a compound helicopter, with fixed wings installed to "unload" the rotor by assuming some of the lift.

The RSRA brings new flexibility and versatility to NASA's rotary-wing flight research program. It operates over a wide speed range, so that the likely flight envelope of any near-future helicopter design could be explored extensively. Both aircraft have been delivered and are flying

at the Ames Research Center.

The RSRA and the XV-15 also can perform additional flight research, once their basic programs have been completed. The RSRA aircraft will be used for studying noise, the dynamics of rotorcraft, and rotor modifications. Both aircraft will be used in the development of avionics systems for improved helicopter operations in both clear and bad weather.

Real-World Environments



Operational and safety problems have been traditional topics for NASA aeronautical research. Flight in bad weather, landings on wet runways, and airport approaches during periods of high-density traffic flow have been studied and improved by NASA programs.

One of the most productive of these is the continuing work on the Terminal-Configured Vehicle (TCV), a research airplane with unique capabilities. The TCV was modified from a standard Boeing 737 twin-engined jet transport by adding a second cockpit, with advanced digital avionics systems, in the passenger cabin of the 737. Two sets of crews may fly the TCV; up front, in the usual positions, is the safety crew. Back in the second cockpit are the pilots who fly the TCV in its research toward improving terminal area capacity and efficiency, and toward improving approach and landing capabilities in bad weather conditions.

In the late 1970s, delays cost the airlines about a half-

The internal arrangement of the NASA Terminal-Configured Vehicle (TCV) is shown in this cutaway model of the modified Boeing 737 aircraft. The test program is flown from the re-

search cockpit, located in the forward fuselage of the TCV. Safety pilots in the conventional cockpit serve as backup to the research pilots, and can fly the airplane as required. Seating

behind the research cockpit is for flight test engineers who monitor and interpret the video display system.

billion dollars annually. Concerned organizations such as NASA, the Federal Aviation Administration, the Air Line Pilots Association, and industry, have been studying ways to increase the handling capacity and capability of the nation's high-density air terminal areas. They believe such increases are excellent ways to increase the productivity of the air traffic control system and the airports.

One suggested partial solution is the use of a time-controlled descent to the airport. FAA air traffic controllers at three major U.S. airports have been working with that method to simplify the control of traffic in the approach. A computer sorts out and sequences arriving aircraft in a time-based traffic control system, matching the

airport demand to its capacity. Adding a "smart" airplane with advanced avionics systems permits the controller to progress from active metering of traffic to passive metering. The TCV program is investigating the techniques needed to achieve the assigned-time objectives accurately and effectively.

Research with the TCV aircraft has shown a consistent ability to place the airplane at a point in space—for example, at the start of the descent to the airport—within a few seconds. If there are unfavorable winds, that time may be increased to as much as ten seconds. But that compares with perhaps two minutes' accuracy with current conventional methods of air traffic control.

The descent itself, handled

by the "smart" avionics in the TCV, is done along a flight path that uses minimum fuel, so that there is a potential fuel saving by using the systems and techniques developed by the TCV programs. Other potential payoff areas include routine operations in bad weather, pilot participation in the traffic control system loop by using a cockpit display of traffic, reduced lateral separation and spacing, and reduced runway occupancy time. All of these factors tend to increase the capacity of an airport in both clear and bad weather.

Bad weather can affect aircraft far from their terminal areas. Boiling up off the midwestern plains in the heat of summer, violent thunderstorms could wrack an aircraft and do serious damage

Small wing-root extensions have been added to a typical agricultural aircraft under study in the full-scale wind tunnel at Langley Research Center. NASA has been investigating the characteristics and operations of agricultural aircraft for many years, and has ongoing programs to improve the performance capabilities, handling qualities, and safety of these specialized airplanes and helicopters. The subject of this specific study was the air flow pattern in the region of the wing-fuselage intersection.

to its structure and systems.

Because thunderstorms are avoided, rather than sought out, there is little detailed data on their characteristics. Their bad qualities are known: Extreme turbulence, lightning strikes, torrential rains and pounding hail storms. But quantifying those characteristics has not been done adequately. NASA has a research program, using test flights of a lightning-hardened General Dynamics F-106B interceptor aircraft, to probe the unknowns of thunderstorms by flying through them, deliberately seeking out lightning strikes and other phenomena to assess their effects on the aircraft. One aspect of this research will be the investigation of ways to protect on-board avionics systems against a direct lightning strike on the aircraft.

The violent turbulence of a thunderstorm has a parallel in the miniature tornado generated by the passage through still air of a large and heavy airplane, such as the wide-bodied transports now operating almost everywhere.

Their wingtips generate a vortex flow, a rotating and expanding cone of high-energy air, strong enough to tumble a smaller and lighter aircraft passing into its field of influence. Much study has gone into understanding and attempting to defeat the trailing vortex because, in some cases, the strengths of these vortices determine the safe spacing between landings at an airport.

One promising solution is the use of an aerodynamic

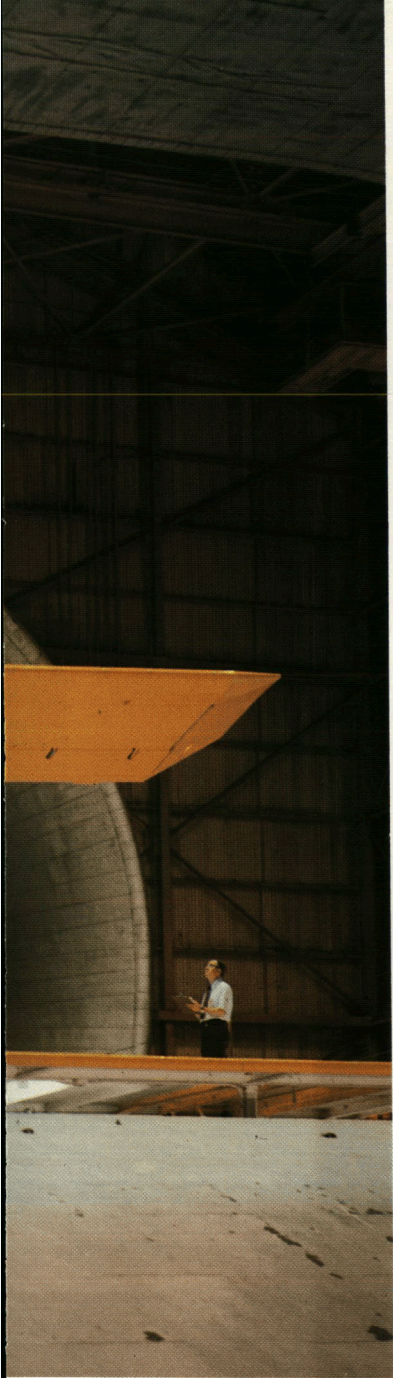
spoiler to break up the vortex. Flight research of spoilers on a modified Boeing 747 is being done, first, as an approach to reducing the strength of the vortex generated by the airplane's passage, and second, to understand the general mechanism of that generation. The method shows promise for reducing the present separation distance from six miles to three, with a corresponding improvement in airport capacity.

As a sidelight, all vortices

are not potentially dangerous or harmful. Generation of a wingtip vortex by agricultural sprayer and duster aircraft helps lay down a swath of insecticide or fertilizer. But not all operators agree that generating a vortex is the best method to distribute material through the wake of the aircraft, and one of NASA's many unusual research programs is investigating ways to spread materials from low-flying planes.



Study in Contrasts




There could hardly be more difference between the shape and function of an angular agricultural aircraft and those of a sleekly contoured supersonic fighter. Yet understanding how both of them work finds common ground in understanding the basic flow fields around them, and the effects their shapes have on that field.

The traditional way to determine flow fields around aircraft has been by calculation, later verified or corrected by wind-tunnel and flight tests. In earlier times,

this routine was done with slide rules and desk calculators. Those techniques resulted in approximations that were accurate enough for the unsophisticated airplanes of the time. But in more recent years, the increasing complexity of aircraft has been matched by the availability of the computer to handle the real chores of airflow computations very rapidly and efficiently. But even the advanced capabilities of contemporary computers are not sufficient to solve the highly complex flow

equations that result from a true three-dimensional situation in the presence of a turbulent boundary-layer flow.

For two-dimensional flow, the situation is different. In 1970, it took the most advanced computer of its day six hours to compute a two-dimensional flow field, excluding the effects of the boundary layer, a thin, slow-moving sheet of air next to the surface. By 1980, computer capabilities had increased so that the same calculation could be performed in five to ten minutes, in-



Aerodynamic evaluation of an agricultural aircraft in the full-scale wind tunnel at the Langley Research Center revealed some potential improvements in this specialized type of aircraft. Tufts were fastened to the external surfaces of the entire airplane for a visual study of air flow patterns. Darkened sectors behind tuft attachment points vividly show regions of air flow instability.

Splitting a model on a vertical plane through the centerline is one method devised by Langley Research Center scientists to reduce to a minimum the interference effects of wind-tunnel mounting arms. In this Unitary Plan wind tunnel at Langley, a model of a supercruiser design concept is being tested. The dividing plane can be seen splitting the model into left and right halves. The wingtip suspension system holds the complete model.

Aerodynamic forces on the left side are measured and are affected minimally by the method of suspension.



cluding the boundary-layer effects.

Reynolds' Number (RN) is a dimensionless parameter used as one basis for comparison of the results of wind-tunnel tests with those of full-scale flight. The closer the Reynolds' numbers correspond, the closer the test results agree. To attain full-scale RN values in a small-scale wind tunnel is very difficult, and the story of wind-tunnel development has been told largely in terms of the quest for higher and higher RN values. High-pressure tunnels have been developed to obtain an increase through an increase in air density. High-speed tunnels also increase the RN value. Use of the largest model size possible raises the value further. The only place left for improvement now seems to be a lowering of the viscosity of the working fluid. And considerations of that need, plus some other problems, led to the development of the NTF tunnel.

It is a cryogenic tunnel; its working fluid is supercooled

nitrogen gas. It is also a pressure tunnel working at nearly nine times the outside atmospheric pressure. Its test section is about 2.5 meters square, and a typical model will have a one-meter wingspan. The predicted values of RN will correspond more nearly to those attained in a much larger wind tunnel, say in a test section on the order of eight meters square.

NASA sees a future need for further increases in capacity and capability of its computational facilities. To put this future need into perspective, consider NASA's most powerful computer on-line in 1980. It handles between 20 and 140 million operations per second, and can store a million "words." To compute some of

the flow patterns around today's and tomorrow's aircraft, scientists foresee a need to process one billion operations each second, and to store 40 million words.

The development and procurement costs for such an advanced computer are high, and the time required for putting it in place is long, so it may well be several years before new computational facilities will go on line.

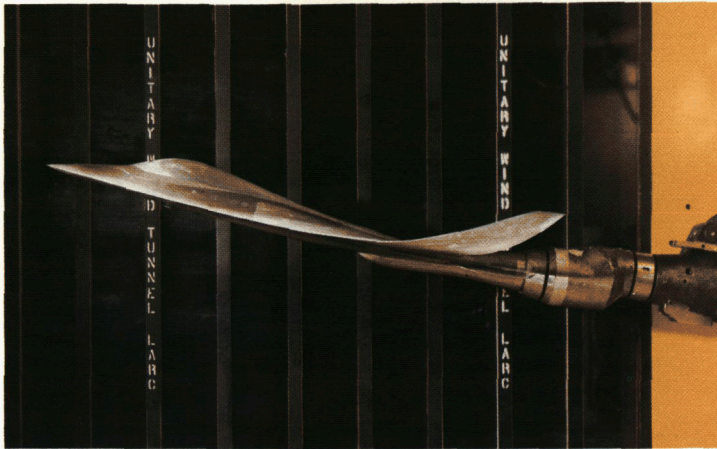
The wind-tunnel facility picture is brighter. Even though this revolutionary computational capability is needed to understand fully the complex flow patterns, the theories still need to be selectively verified by experiment. Assisting in this verification of theory are advanced research tools such as

the National Transonic Facility (NTF) tunnel, scheduled to start calibration runs in 1983. When it is fully operational, it will increase greatly NASA's ability to obtain accurate wind-tunnel predictions of full-scale phenomena. The key is the attainability of large Reynolds' numbers. Wind tunnels have other problems, since they are not perfect research tools. For example, the presence of the test section wall is an artificial constraint on any testing. No real airplane flies around surrounded by a solid surface that does not match the streamlines of flow. But suppose a wind-tunnel wall could be made to conform to those shapes? Some early research and tests reflect optimism

Fast, Faster, Fastest...

Conceptual model of a supercruiser fighter design shows one of the characteristic aerodynamic shapes evolved in the NASA study program. The geometry is that of a blended wing-body configuration, using a highly swept delta wing as the basic shape, and adding the unusual wingtips which are swept

aft and up. This particular model is being tested in one of the Langley Unitary Plan wind tunnels, using a unique method of suspension to reduce model support interference to an absolute minimum. The model is split longitudinally along a vertical plane through the centerline.



that it can be done. NASA, working in conjunction with British scientists at the University of Southampton, has devised an adaptive wall that is self-streamlining. It has a flexible floor and ceiling, and ways to measure the pressure pattern inside the test section. Using that pressure data and other information, the tunnel test section adjusts its shape until the flow through it matches the computed velocity distribution in free air.

Models are held in any wind tunnel generally at the end of a long arm, filled with measurement systems that sense the movement of the arm and translate that into force measurements. But the very presence of that arm in the test section affects the validity of the tests. What is

needed is no physical suspension at all. The model should be free in space, the way its real counterpart is.

Researchers at NASA and abroad have been studying this particular problem for some years, and have begun to evolve a system of magnetic suspension that does not intrude into the test section. The model is held in a strong magnetic field, and is free of any interference effects that might be caused by a conventional suspension system.

The new NTF eventually may incorporate these latter two concepts in its test section. Developmental systems have been built on smaller scales and have been tested for applicability.

The demand for flight at higher and higher speeds has been a major reason for the development of such advanced analytical and research tools as future computers and the National Transonic Facility. Historically, increases in speed have been associated with the development of military aircraft, particularly fighters. More recently, the program for an American supersonic transport generated some new and different requirements for high-speed aircraft design. Most recently, after the cancellation of the SST and the shift in emphasis to supersonic research aimed at fighter design, a number of modern technologies became part of the synthesis. And synthesis it is; no modern airplane is designed around a single predominant feature. Now it must use the best of the contemporary arts and sciences in aerodynamics, structural concepts, propulsion, control, materials and avionics. To do less is to doom the design to a second-rate position.

Speed and maneuverability are the major qualities sought for a military fighter aircraft, and they are needed for its offensive performance as well as for its own defense. But speed and maneuverability have tended to be mutually exclusive. The high-speed fighters of the past did their best maneuvering at velocities well below their maxima, and at peak speed performance were capable only of gentle turns. That no longer is good enough, and the latest military designs, including such in-service types as the McDonnell-Douglas F-15A and the General Dynamics F-16A, show combinations of speed and maneuverability never before achieved.

It's difficult to build maneuverability into a combination of a high-speed airframe and a human pilot. High maneuverability subjects the airframe to loads that are several times normal and frequently unsymmetrical. It imposes a severe strain on the aircraft, the pilot, and all the control systems. It may even trigger

The HiMAT vehicle used in NASA's program to study Highly Maneuverable Aircraft Technology is a scaled-down remotely piloted research aircraft. This experimental technique was developed by NASA several years ago and is useful to study high-risk technologies. Further, tests with small-scale, unmanned

models are more economical. The HiMAT vehicle is carried aloft by a modified Boeing B-52 mother ship and launched at altitude, typically 45,000 feet. It can fly for approximately 20 to 25 minutes after release, landing on the dry lake bed at the Dryden Flight Research Center, Edwards, California.



an aerodynamic instability of some sort that may cause the airplane to whip out of control.

The studies of the interrelations of all these factors, done by NASA, the military services' laboratories, and industry, have coalesced around a single program called HiMAT (Highly Maneuverable Aircraft Technology). It is another example of NASA's approach to research, because HiMAT began as a series of analytical and computerized studies, progressed to tests of scale models in a number of wind tunnels, and now is in the flight-research stage, using unmanned, remotely piloted vehicles approximately half the size of a typical fighter design.

HiMAT has two basic tasks. First, it is used to study the interrelated problems of all aspects of the flight of a typical advanced fighter configuration. Second, it is contributing to the design of future fighter types by furnishing fundamental aerodynamic and structural loads data that

will assist designers in industry.

HiMAT is a joint NASA/USAF program, with the design and construction of its test vehicles being the responsibility of Rockwell International's Los Angeles Aircraft Division. The basic concept of HiMAT is that of a close-coupled canard layout, with advanced airfoil design and aeroelastic tailoring. It is a subscale model of an advanced fighter, synthesized by Rockwell designers as typical of the year 1990.

The detailed design specified a core vehicle with a basic engine, airframe and systems. The remaining components were designed as modules that could easily be attached to the core vehicle, and just as easily replaced by different or developed units as the program progressed.

Composite materials account for nearly one-third of the airframe structural weight of the HiMAT vehicles and, for the first time, these new materials are being used to capitalize on the ability to give them unidirectional



The HiMAT vehicle makes its final approach for landing on the lake bed at the Dryden Flight Research Center, Edwards, California. It uses landing skis rather than wheels to absorb the

stiffness. The composite wing and canard surfaces are designed so that the natural bending of both surfaces under maneuvering loads will control the changing of the aerodynamic shape of the HiMAT to maintain optimum lift and drag conditions.

Flights of HiMAT begin with an air launch from a modified Boeing B-52D aircraft. The research pilot sits in a cockpit on the ground at NASA's Dryden Flight Re-

search Center, and he flies the vehicle from there, monitoring its performance on a series of displays typical of a fighter cockpit. A backup controller, aloft in a Lockheed TF-104G, can assume command of HiMAT if ground control is lost. And, should both fail, the vehicle automatically goes into continuous turning flight and will stay in that maneuver until control is regained by either pilot.

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Single Pivot for a Wing



lifting characteristics of its unique configuration. HiMAT is a joint project of NASA and the U.S. Air Force. This picture shows the vehicle near the completion of its third test flight.

The basic technique of remotely piloted flight was developed by NASA at the Dryden center, and has been used in earlier test programs, for example, stall and spin research on a scale model of the McDonnell-Douglas F-15A.

The advantages of such a research program as HiMAT are readily apparent. Its modular design makes it relatively easy to change a major component, such as an engine inlet or nozzle, and to evalu-

ate it under test conditions in free flight. Its smaller scale serves to reduce costs, both initially and operationally. Its size also allows it to be tested in large wind tunnels, for direct comparison of aerodynamic data with free-flight results. And with a pilotless vehicle, the extremes of the flight and maneuverability envelope can be explored without the need to put a pilot's life at risk.

There's an old saying in aviation that if an airplane looks right, it will fly right. There is also an old maxim that every rule has an exception. Combine these, and you have an impression of the NASA oblique-wing aircraft, a concept that looks as wrong as possible. On one side, a wing lunges forward to meet the oncoming air; on the other side, it sweeps back.

And it flies right.

This radical departure from the conventional geometry of aircraft layouts was devised by NASA's Robert T. Jones, and first advanced by him several decades ago. Great skepticism greeted the idea, even though it had been tested in a wind tunnel and seemed to be workable. But at that stage of the art, it may have been impractical to provide the structure required to perform the unique task of sweeping one-half of the wing forward and the other half back.

With the advent of composite materials, and their unique ability to be tailored to carry loads along any desired di-

rection, the oblique wing concept called for a second look. Jones had never abandoned the idea and, in fact, had continued to develop it in scale-model testing. He used small radio-controlled models which flew well and continued to dumfound the casual observer.

Oblique wing studies had been extended earlier to the requirements of supersonic flight and had shown, surprisingly to some, that the odd shape offered a major advantage in the design of a supersonic transport. Analysis and wind-tunnel work done at Ames Research Center pointed to a fuel economy twice as good as that of the first generation of operational supersonic transports. There was a bonus: The concept seemed to produce a substantially weaker sonic boom, one of the banes of supersonic flight.

NASA funded the design and construction of a small, piloted research aircraft with a pivoting wing. This proof-of-concept vehicle was built by the Ames Industrial Corp.,



Bohemia, NY, and the aircraft now is flying in an exploratory program that will check out the subsonic flight characteristics of the unusual wing concept. The research vehicle, designated the AD-1, is built of foam and fiberglass. It has a 32-foot wingspan and a 40-foot length, and weighs in at a total of 1,800 pounds. Its powerplant is a pair of 200-pound thrust turbojet engines.

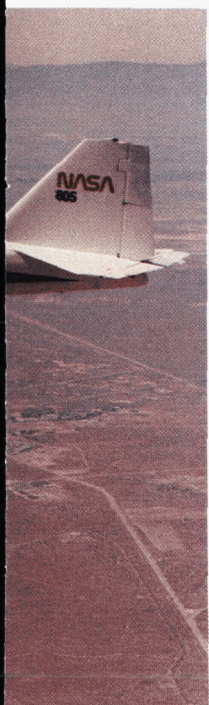

For low-speed flight, the wing stays at a right angle to the fuselage centerline, and provides all of the excellent characteristics of a straight-

winged airplane. In that configuration, it has good stability and control qualities, no need for ornate high-lift systems, and reduced engine thrust for takeoff. For high-speed flight, the wing pivots to angles up to 60 degrees with respect to the aircraft centerline. The drag is decreased substantially.

Once again, the progression from an idea through analysis, wind-tunnel tests and into flight research underscores NASA's systematic approach to a new and unique concept for the improvement of aeronautics.



The Science of Shapes



The Ames-Dryden-1 (AD-1), photographed during a test flight from NASA's Dryden Flight Research Center, is being flown to study the concept of the oblique wing. Invented by Ames Research Center scientist Robert T. Jones, the oblique wing is pivoted at a central point spanwise. Rotated by actuators, one wing tip moves forward and the other aft to sweep angles up to 60 degrees with the fuselage centerline. This aircraft, flown by pilots of the Dryden Flight Research Center, is an example of the NASA "proof-of-concept" approach in aeronautical research.

One of the historic tasks at NASA has been the development of new shapes of flight. The years have seen the biplane, with its struts and wires, give way to the cantilevered monoplane. Straight wings made way for sweep-back, then for variable sweep, with the special case of the oblique wing mentioned above. The search for more speed and more efficient aircraft has recently led to a family of shapes in which the wing and the fuselage are blended into an integrated whole of sweeping and curving surfaces.

Part of this work has been aimed at the "supercruise" class of airplanes, designs that are intended to fly economically and efficiently at supersonic speeds. At first, NASA programs in this area concentrated on the specific needs of the U.S. supersonic transport. But now the work is aimed primarily at the development of new shapes for fighter aircraft, shapes that will permit unusual maneuverability coupled with dazzling speed and the ability

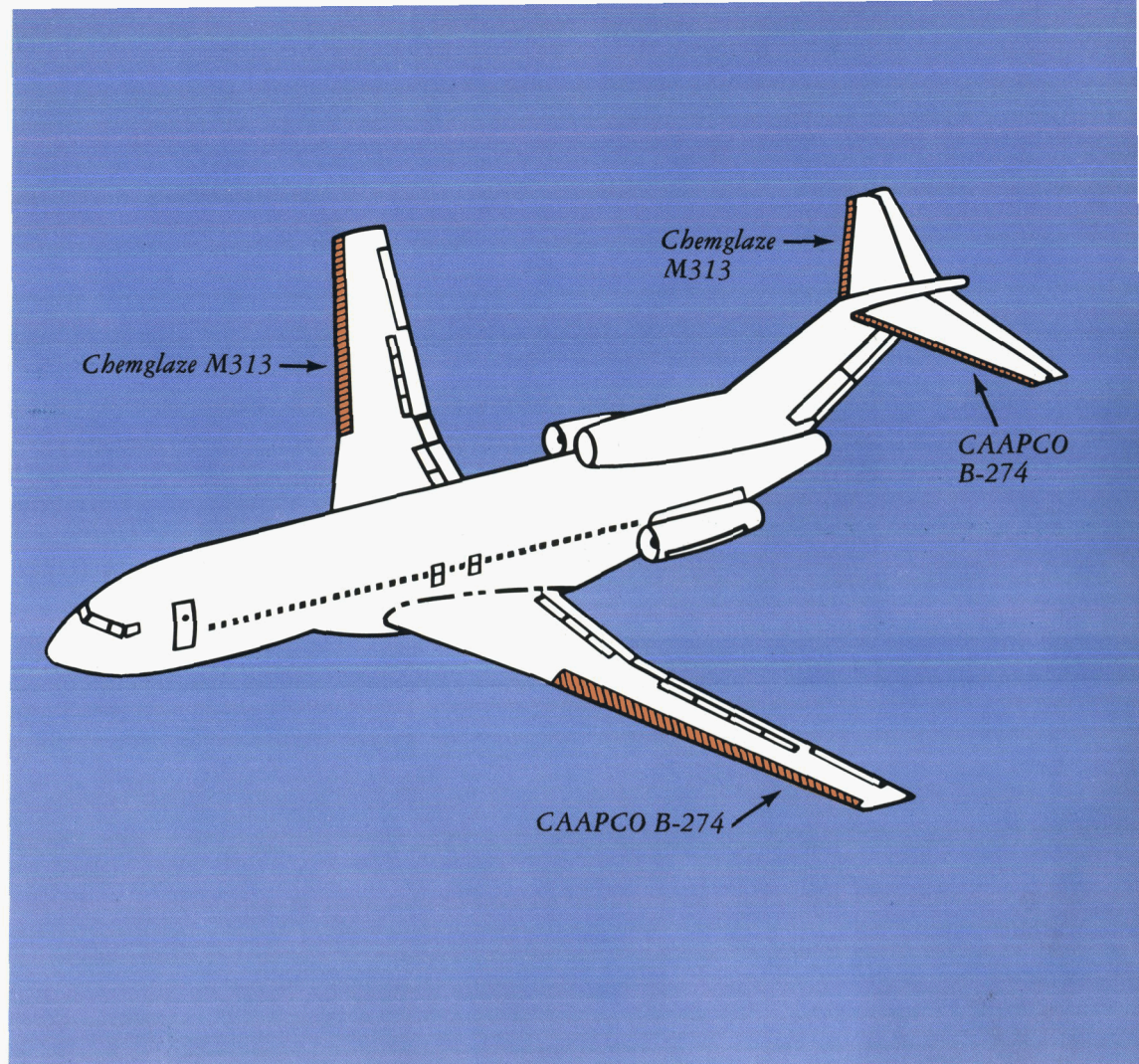
to accelerate to supersonic flight rapidly and efficiently.

One of the things learned in these studies has been the importance of the strake, a fairing that stretches from the leading edge of the wing to a point forward on the fuselage. On a very high speed aircraft, that strake may become a major portion of the lifting surface. It can be used to create a vortex that generates lift, and to apply that lift toward maneuverability. The concept is an exciting one, and it is finding applications in the new generation of fighter aircraft.

Aircraft efficiency is measured simply; it is the ratio of lift to drag. The higher that ratio, the more efficient the airplane. The major problem in supersonic flight is that the lift-drag ratio inherently has not been high, and it has not been easy to raise the modest values that are routinely attained.

Consequently, NASA has been analyzing ways to increase lift and reduce drag of wings, shaping them to the needs of supersonic flight. As

Experiments with plastic coatings to reduce skin friction drag on wing and tail surfaces are being done on a Boeing 727 operated by Air Micronesia in a tropical environment. Two different types of coatings—Chemglaze M313 and CAAPCO B-274—are being evaluated for drag reduction and resistance to the particular environmental factors of the air operations in Micronesia. Potential fuel savings from small drag reductions are substantial, and increase with the increasing cost of jet fuel. This sketch shows the location and extent of the plastic coatings.



a further refinement, these wings then are fitted with a variety of high-lift devices, to improve their characteristics in the takeoff and landing regimes of flight. Some of these ideas are finding applications in the ACEE program as well as on the futuristic shapes being developed for tomorrow's fighting aircraft.

Chasing down drag is an endless task. No sooner does one component seem to have been brought to the irreducible minimum of drag production than another shows as a contributor of sizable drag increment to the aircraft. A jet engine installation on a contemporary transport is a typical example. There is a flow interference in the region between the wing and the engine nacelle, and it adds a substantial sum to the total drag of the aircraft. And because there are, typically, either two or four of these intersections between wing and nacelle on today's transports, it's a region worth exploring with the aim of reducing its contribution to aircraft drag.

NASA investigators are

concentrating on proper shaping of the pylon that holds the engine nacelle to the wing, looking to smooth the flow under the wing and to reduce any tendencies for a crossflow to develop. Wind-tunnel tests of pylon redesigns and other modifications have shown ways to reduce their drag contribution.

Aircraft control surfaces are sized to meet the stability and control requirements spelled out in Federal Aviation Administration or other cognizant agency regulations and handbooks. The surfaces are large, because they are designed to static stability requirements. The tail surfaces act like a weathervane's tail; they keep the airplane—or the weathervane—pointed into the relative wind. They are passive controls; they

react to a disturbance.

Active controls are a subject under major study at NASA. The approach is on the basis of what are called "relaxed" stability requirements, in which an instability is anticipated by sensors and transformed into signals to the control surfaces to correct for that instability even as it is occurring. By doing that, the control surfaces can be made smaller, and therefore lighter, than normally. Anything that saves weight and size also reduces the drag and the amount of power required to fly. And that, in turn, reduces the amount of fuel burned. So the active control programs under investigation at NASA have been aimed at the broad goals of the ACEE efforts, and in related studies for applications outside the transport field.

An obvious way to reduce airplane drag is to wax its surface. On a small personal aircraft that's feasible; on a Boeing 747 it's not very practical. But coating the airplane with some sort of a synthetic surface might achieve the same results as hours and hours spent waxing the exterior. NASA has funded a study of airplane coatings with Air Micronesia, whose Boeing 727s work in the South Pacific islands, in an environment of sand and coral abrasion, torrential rains, torrid Sun, and salt spray. The leading edges of the wings and tail of one of the airline's 727s have been coated, and are being studied over a long time period to assess the effects of the coatings on performance, and the effects of the environment on the coatings.

General Aviation Programs

General aviation is a catch-all term to describe a very important segment of aeronautics. It includes all of private flying, all of corporate and executive transportation, all of agricultural flying, much of the newly emerging commuter air transportation market, and a miscellany of antique aircraft, restored museum pieces, homebuilt planes, gliders, and hot-air balloons. The list is long, and indicative of the variety and growing importance of general aviation.

NASA's interest in this always-growing field goes back to the early 1920s, and the early years of the NACA. Even then, the agency was investigating ways to make personal aircraft more reliable, safer, and more efficient.

Currently, NASA focuses its attention on several basic problem areas in general aviation. The first, and most important, is improving safety. A second is improving the environmental characteristics of the aircraft and engines, reducing their noise levels and emissions of exhaust

Leading-edge slats, extending well forward of the outer wing panels of this typical light twin-engined general aviation aircraft, were evaluated in Langley Research Center's full-scale wind tunnel. Wing and engine nacelle surfaces carry

products. A third is improving the energy efficiency by improving the performance of major components and systems. NASA also has emphasized increased utility in its studies.

One way to improve safety is to study how airplanes crash, in the hope of finding some basic structural or other design changes that will increase the survivability of crew and passengers in an accident. For several years, NASA has been deliberately crashing a number of single- and twin-engined lightplanes

hundreds of tufts, used as visual indicators of the direction and type of local air flow. This particular test was part of a continuing series at NASA to study, evaluate, and derive aerodynamic improvements for typical general aviation air-

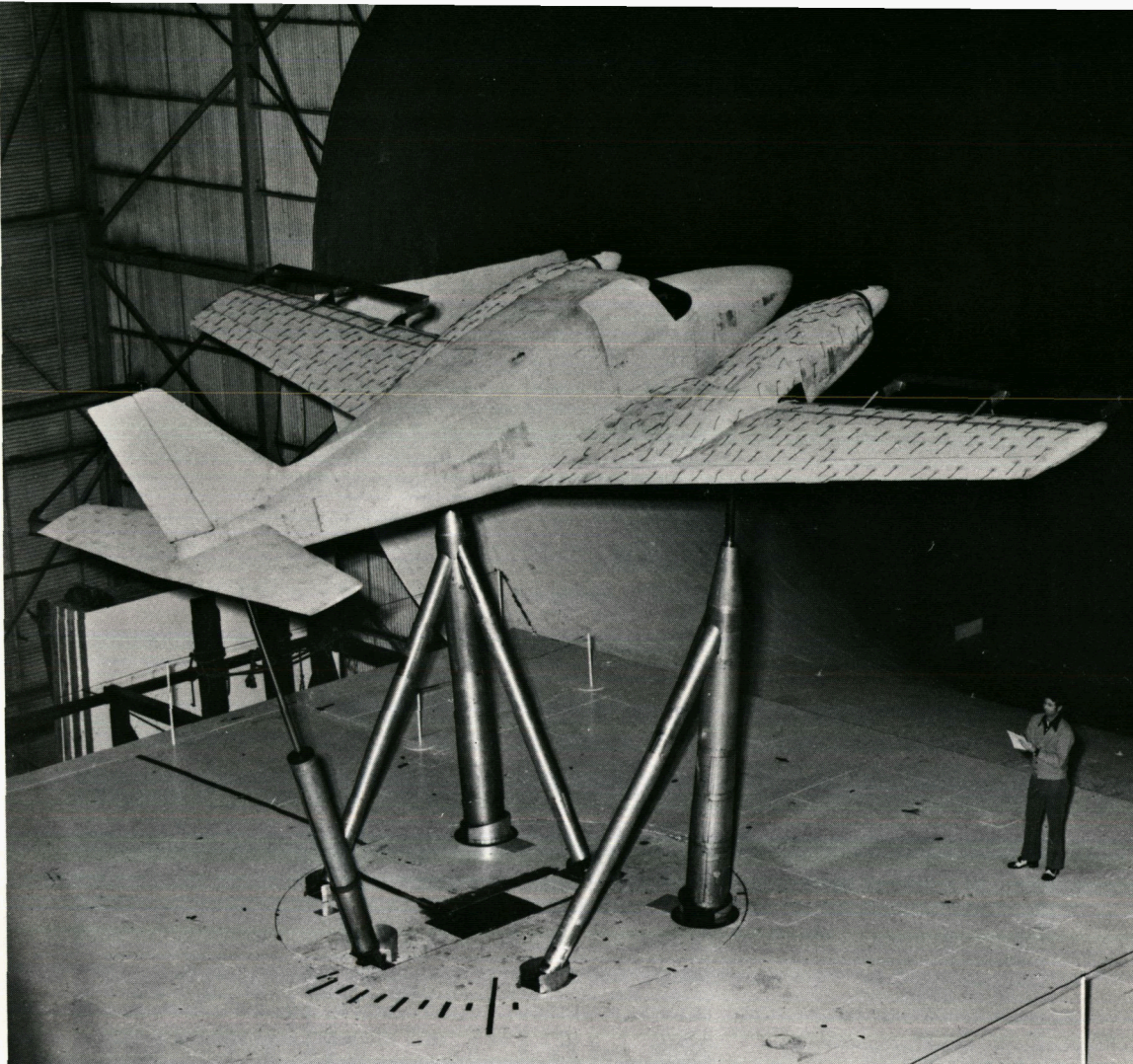
craft. These full-scale tunnel tests can later be correlated with actual flight tests of the aircraft, to determine the degree of agreement between the two sets of results.

in a carefully controlled, instrumented and documented series of spectacular impacts. As the result of a flood a few years ago, which inundated the final assembly lines of a major manufacturer of general aviation aircraft, NASA acquired a number of nearly completed airframes. These had been condemned as un-airworthy because of water damage, but they became useful research tools.

The crash tests at the Langley center have progressed from the early few, which were essentially guided

free-falls onto concrete pavement. More recently, small rocket motors have been installed in the engine nacelles to boost the impact velocity in a simulation of crashes at higher speeds.

Extensive instrumentation in the aircraft as well as outside, high-speed photography, and other means are used to acquire data and to document the crashes. Anthropomorphic dummies are harnessed in crew and passenger positions, instrumented and photographed to assess their



This spectacular photograph shows a light twin-engined general aviation aircraft moments before its impact with a runway surface in the seventeenth of a series of crash tests at the Langley Research Center. Flame streaks are the exhaust of four solid-propellant rockets which thrust the plane to a higher impact speed than is possible in a simple gravity-accelerated drop. The impact occurs in front of a gridded backdrop which allows measurements of aircraft accelerations and decelerations.

chances of surviving the deliberate crash.

One investigation that uses this test environment is a study of energy-absorbing aircraft seat design. New concepts in passenger seats, evaluated in high-speed rocket sled tests by the FAA's Civil Air Aeromedical Institute, later were installed in test airframes for the crashes.

In a related effort, energy-absorbing structural design techniques were used to modify the fuselages of crash-test airframes. Post-crash examination of the fuselages and the instrumentation results was used to assess the applicability of the new designs for future light aircraft.

The best way to survive an accident is not to have one, of course. One of the major long-term areas of NASA's activity in general aviation is in the investigation of stalls and the spins that sometime follow. A leading cause of civil air accidents, the stall/spin is a phenomenon that increasingly is being understood, analyzed, and coun-



tered. Typically, research starts with a small dynamically similar model of an airplane which is tested in the spin tunnel at Langley. Recently, these tests have been followed by free-flights of radio-controlled scale models, and finally by flight research with the real aircraft. Several general aviation aircraft serve NASA as vehicles for stall/

spin flight research. One was modified so that a number of vertical tail designs could be installed for investigation of their effect on the stall/spin recovery. Other design modifications have included the addition of strakes (fin-like surfaces) and, most important of all, changes to wing leading edge configura-

tion has been discovered to have a powerful effect on spin resistance.

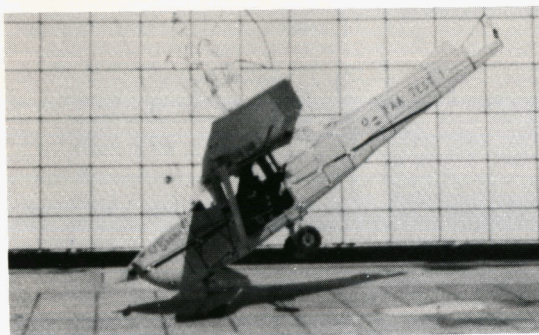
A major program to demonstrate the technology for a Quiet, Clean General Aviation Turbofan (QCGAT) engine was established by the Lewis Research Center, with funded contract work placed with industry. The goal was to show that the technology of

The suspension system that assures the correct angle of impact with the concrete surface in these NASA crash tests is being checked here before hoisting the light twin-engined aircraft to its release point. This test, seventeenth in a series of controlled crashes to investigate aircraft structural behavior following impact, used four solid-propellant rockets mounted in the rear of the engine nacelles to accelerate the airframe to a higher speed than possible with a gravity drop. External paint scheme defines the internal structure of the aircraft, so that high-speed photography can show the progression of airframe reaction after impact.



noise and emission reduction, common to large turbofan engines, could be transferred to the design and development of turbofan engines in thrust categories useful for some general aviation aircraft. Garrett's AiResearch Manufacturing Co. and Avco Lycoming each modified an existing engine in their commercial line to meet the requirements of the program. The major effort was directed toward reducing the noise level, and that was achieved in both engines. A second goal was to reduce the carbon monoxide, unburned hydrocarbons, and oxides of nitrogen emitted; that, too, was achieved. One constraint was to accomplish these reductions without any increases in the fuel consumption. Actually, the fuel consumption decreased significantly.

A series of four study programs, also with industry, looked at the feasibility of developing small turboprop engines for general aviation in the 300 to 700 shafthorsepower range, where they could compete with highly

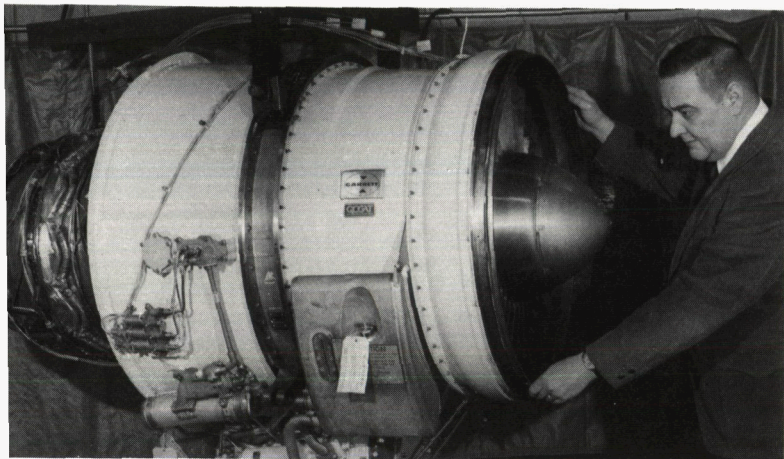


Aircraft structure behavior on impact with the ground is being studied in an on-going program at the Langley Research Center. Using planes typical of the light single- and twin-engined aircraft in general aviation use, NASA engineers deliberately release the planes along a controlled flight path onto a concrete apron. Highspeed cameras and other instrumentation record the loads, decelerations and distortions of the aircraft. Instrumented anthropomorphic dummies, which accurately simulate the human frame, may be included in the test to study the survivability aspects of a particular type of impact. This sequence reads from top to bottom, to show the stages from initial impact through subsequent deceleration to a stop. Both NASA and the FAA support this test program as one way of helping to increase occupant survivability in general aviation accidents.

Building It Stronger

One of two competing quiet, clean general aviation turboprop engines (QCGAT), developed under contracts funded by NASA's Lewis Research Center, shows the general configuration of the powerplant. Purpose of the program was to demonstrate transfer of technology from commercially available, large turboprop engines to smaller engines in a lower power class. Garrett's

AiResearch Manufacturing Company—their engine is shown here—and Avco Lycoming both developed an existing engine to the requirements of general aviation. Both manufacturers achieved major reductions in noise level, and in the emission levels for carbon monoxide and unburned hydrocarbons.



developed internal combustion engines. The aim of the studies was to see if such engines appeared feasible in the light of fuel consumption, weight and cost constraints. The studies indicate that this should be possible with advanced technology engine components and manufacturing techniques. Advanced technology programs are being proposed to achieve these objectives.

Additionally, propeller design, frozen in the past with few exceptions, has been long overdue for a transfusion of modern technology. NASA has been looking at ways to

increase propeller efficiency, through such possible changes as the use of modern airfoils instead of the older conventional airfoils normally used. New designs include NASA's supercritical airfoil technology for appropriate flow regimes. The composite materials also offer promise, because the indications are that propellers could be built with less weight and with better structural characteristics and fatigue life using modern composite structural design technology. Further, their aerodynamic performance would show a major improvement.

The dynamics of the aircraft crashes at Langley have led to the development of new seat design concepts and seat restraint systems. But they also have led to a careful analysis of the way an airframe is damaged in a crash, how the progressive destruction of the airframe moves from the point of impact throughout the structure. It may be that some simple changes will be found to increase the crashworthiness of aircraft. These studies have been extrapolated to large transports, and all three major manufacturers of airliners have NASA contracts to investigate the problem of crashworthiness in airplanes of the size they design and build.

Understanding how something fails is the key to efficient design of that piece. Knowing that, the design can take into account some special feature that will delay or even prevent a specific mode of failure. One example is the use of small extruded strips of metal on a pressurized fuselage skin panel to act as rip-stoppers. Another example is the tailoring of a composite structure to absorb the load

along an axis of particular strength.

Composites seem to be very useful materials for aircraft structures. Made from fibers of carbon or other high-strength substances imbedded in a matrix, these new materials can be formed into structures replacing many components of modern aircraft. NASA has a long-term program in which control surfaces, stabilizers, and fuselage fairings have been designed and built using composites. These parts, installed as replacement units on commercial transports, are in long-term airline use to evaluate their durability in the real world of routine operations.

These composite structures are very light and very strong; they can be made very stiff, also. Or, the strength and deflection can be applied along a specific path, or about a specific axis. Other NASA composite structures are found in the HiMAT research vehicles, and in a series of sub-scale test wings being flown on drones into a high-speed aerodynamic regime where flutter is studied.

The Future of Aeronautics

In 1980, the cost of everything was of major concern, and the price of NASA research was no exception. Cost considerations have been the major reason behind the sometimes slow pace of aeronautical research. But, because industry finds itself facing the same problems, it has been turning increasingly to NASA for the funding of research programs that might have been regarded as proprietary subjects a few years ago. A strong case can be made for doing the kind of research that industry wants and needs, based on the NASA charter defined by the 1958 National Aeronautics and Space Act.

NASA's record has shown that its research and technology programs have advanced the progress of aviation. Its present programs are making valuable and timely contributions to the design of advanced fighters, to the safety of general aviation, to the improvement of air transport operations in areas of high-density traffic. NASA's future plans for modernization, such as those for the National Transonic Facility, were con-

ceived in the best tradition of aeronautical research. That tradition, which began in 1915 with the establishment of the National Advisory Committee for Aeronautics, is a great intangible advantage that pervades the staff and laboratories of today's NASA. Together, they constitute a national asset of great worth, of past proven performances, and of enormous future potential.

The HiMAT vehicle used in NASA's program to study Highly Maneuverable Aircraft Technology is a scaled-down remotely piloted research aircraft.





National
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Administration

Public Affairs Division
NASA Headquarters
Washington, DC 20546

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